
Measuring Access to Primary Health Care: Use of a GIS-Based Accessibility Analysis

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ABSTRACT

Spatial analytical tools and analyses are key enabling instruments which can be used to efficiently plan for public-spaces such as health care facilities in a metropolitan context. Improving the levels of access to public-spaces through various planning approaches is necessary especially in light of the magnitude of development in metropolitan areas. However, planning for the provision of services in the health care sector is somewhat more complicated than planning for any other type of service. In the perfect world, health service delivery systems would be able to cater for all the health care needs of the entire population. However, realistically speaking, this has currently proven unattainable as the health care needs of people differ along many dimensions. Health care service planning requires consideration of a range of issues when looking at serving the health care needs of a spatially dispersed population. From the perspective of the provider, the challenge is therefore to optimally provide services in such a way that the health care needs of the greatest number of people are served. Recent increases in the availability of Geographical Information Systems (GIS) and associated modelling approaches have provided a good basis for the planning for the need of public services. Successful applications of these approaches have been useful in indicating average accessibility of an existing or potential service. However, it is increasingly realised that there has been a growing need for a paradigm shift in planning approaches. The spatial planning of primary health care services based on GIS accessibility analysis has only been used to a very limited extent in South Africa. In this study, facility utilisation rates in the form of headcounts are incorporated in a GIS-based accessibility analysis to assist in the spatial planning of health care services. Due to the absence of accurate patient databases and / or registers, GIS tools are used to determine three different scenarios of defining public primary health care demand. The three scenarios are tested in a GIS-based form of catchment area modelling. The results show no significant difference in the spatial extent of the catchment areas of facilities but a significant increase in the allocated demand from scenario 1 through to scenario 3. When compared to the facility headcounts, the total allocated demand in scenario 3 tends to be more strongly in line with the total number of facility headcounts recorded in the city showing a moderate positive correlation. This type of analysis promotes and facilitates the development of future facility plans in relation to actual demand and usage, and also improving current service provision access at overburdened focal points where previously not realised.

KEYWORDS

Accessibility, Utilisation, Health Care, Services, Planning, GIS

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1. INTRODUCTION

One of the primary objectives when publicly providing health care services is to achieve social and spatial equity. The concept of equity has been known to connote fairness and justice in the distribution of resources and liabilities in any society (Samuel & Adagbasa, 2014:270). For instance, the distribution of health care resources must be in balance with the need of the population. But then again health care, like many services that are provided as a public good, is not equally available and accessible by all individuals.

A decision to locate any public facility in a geographic area is essentially to distribute a certain type of public service among different groups of people. Such decision making is intended, in some way, to equitably provide the services for various groups in the population. Basic to this decision making is the concept of access. Two important geographical perspectives on health care service access can be distinguished: (1) Accessibility (potential accessibility) - availability of a service and means of reaching it; and (2) Utilisation (revealed accessibility) - actual use of available services. This study mainly deals with the first perspective by particularly using a service access planning approach to determine public primary health care demand in a metropolitan context. The approach is then supplemented by incorporating the facility utilisation statistics as related to the second perspective.

1.1 Access to health care

Political changes during the past decades have increased people's movement and this has given rise to a number of challenges about serving the basic health care needs of a dispersed population. Depending on the development context of a country, the way in which access is looked at will differ. Gulliford and Morgan (2003:1) state that in low-income countries problems of access concern the availability and accessibility of basic services such as the ability to visit a doctor or to receive health care during pregnancy and delivery for example. Whereas in affluent countries basic services are generally accessible, questions of access concern the degree of comprehensiveness that can be offered by health care systems, the extent to which equity is achieved, and the timelessness and outcomes of care (Gulliford & Morgan, 2003:1).

Poor levels of access to health care services by the population have become a major concern in developing countries. In Sub-Saharan Africa one of the main problems with health care service provision is that it is often not accessible to those in need. The provision of adequate health care services, particularly in urban areas, is becoming more difficult because of the outcome of three developments; (1) the rapid growth of cities and their population, (2) urbanisation of poverty, and (3) slow economic growth (Amer; 2007:3). These continuous developments have led to increased population densities in urban areas with limited health care resources which result in, for example, shortage of resources in facilities, long queues and increased waiting times.

In South Africa people often face great inconvenience, travel long distances and visit more than one service point to obtain the health care services they need from government facilities (DPSA, 2011). This is due to the fact that some of these people form part of the low-income population who tend to reside in the more peripheral locations of the urban areas or marginalised areas of the city. This shows that while some areas of South African cities are well connected and integrated within the areas surrounding them, others are not. Besides that fact that these areas have a poor level of macro-accessibility as a result of their peripheral location in relation to major metropolitan facilities (e.g. hospitals.), these areas also generally suffer from a low level of service availability, quality and accessibility in relation to local-

population serving facilities such as clinics and community health centres (Green *et al.*, 1997:1-1). This point is also made by Samuel and Adagbasa (2014:267) when they state that many urban dwellers especially in the Sub-Saharan Africa have to travel long distances within the urban space to access basic health services. In addition most low-income and marginalised people's mobility is usually determined by their economic conditions.

1.2 Towards improved spatial access

It is widely acknowledged that the provision of services should be planned so as to effectively contribute to the development of quality living environment. While it is important for the sectors responsible for the provision of health care services to locate facilities in such a way as to serve the majority of the population, it is also important to note that metropolitan areas, however, are dynamic and continue to develop and expand with time. The last few years have seen South African metropolitan areas increase in population densities and thus putting more pressure on already overburdened service delivery systems. The challenge for health care planners is thus to adequately plan for the provision health care services to the greatest number of people, taking into account future demand while efficiently using current deficient resources.

Service provision for publicly provided facilities with quality services and infrastructure for improved access is better approached through proper planning. The spatial planning of health care services involves aspects of resource allocation. Access to health care facilities is one of the important facets in the health care planning process. Given the spatial perspective of this study, performance is then assessed in terms of geographical access levels of the services by potential users. GIS-based accessibility analysis is a logical method which can be applied to measure the degree to which geographical access is obtained. It has recently been used to approximate the degree of health care need and / or forecast health care demand in a number of studies (e.g. McGrail, 2012; Al-Taiar *et al.*, 2010, Apparicio & Séguin, 2006, Bagheri *et al.*, 2005 & Lin *et al.*, 2005). Simply put, GIS-based accessibility analysis is a relational evaluation of services relative to potential user's demand measured within a specified distance range and using a detailed road network. This type of analysis is therefore not a simple service-to-population ratio. A key advantage of measuring accessibility is that the measurements take into account service sufficiency (capacity) with respect to its location.

2. LITERATURE REVIEW

Although access is in the first instance a spatial condition, it is now a key concept in service planning. However, as current deliberations have indicated, there has been considerable confusion about what the concept of access means. It is therefore important to mention at the outset that the definition used will depend on the aim and context of the study. The aim of this research as a whole was to determine public primary health care demand. This means that the focus here was the relationship between the location of services and the location of clients taking into account travel resources, time and / or distance (Penchansky and Thomas, 1981:128). Thus access has been used here to refer to:

'When considering people, accessibility is about "the ease with which any individual or group of people can reach an opportunity or defined set of opportunities"; this is often referred to as origin accessibility. When considering service providers, accessibility is "the ease with which a given destination can be reached from an origin or set of origins" (Simmonds et al., 1998); this is usually referred to as destination accessibility, catchment accessibility or facility accessibility.' Halden et al. (2005:3)

Therefore the overall level of accessibility, be it potential or revealed, can be used as an indicator of the health service delivery system's performance. Literature has highlighted that measuring the performance of a health care service delivery system has become a challenge. This challenge is

compounded by the task of translating the relevant data into a format that is clear and persuasive to policymakers and funding agencies (Phillips *et al.*, 2000:971).

Data is fundamental to any type of research. A key factor in strategic and operational planning is the availability of appropriate data and information, which can be used in decision-making (Abbot, 1996:2). The successful completion of any research depends critically on timely, organised and accurate data. But when it comes to health services research data is often unavailable or provided at different temporal and spatial scales. This is particularly true for South Africa, and Scott *et al.* (2002) drew attention to the limitations of existing data sources in a study that focused on creating a health information system for cancer patients in KwaZulu-Natal. Just to mention a few, the limitations include (1) privacy and confidentiality restrictions limiting access to data about health status and health outcomes especially for individuals or for small areas, (2) data on health care utilisation and treatments are often proprietary, controlled by health insurers and provider organisations, and (3) for public data, there are problems with compatibility and sharing of information among agencies (McLafferty, 2003:37).

Nevertheless, the use of GIS in South Africa for assessing service provision and developing facility plans leading to improvements in governance and equitable service delivery is well underway. There is a developing need to focus on improved measures of access to local public facilities, and the need to find practical tools to support and improve current facility planning practice (Green *et al.*; 1997:1-1). The traditional approach to measuring access, for years, has been the number of facilities to population ratio as a measure of availability by the distance or time travelled to the nearest or by the number of facilities in a geographic area. These measures, however, do not handle properly such peculiarities as the use of services in other communities, the failure to use the nearest facility, overlapping coverages, redundant services (Rosero-Bixby, 2004:1273). In addition, measuring accessibility using GIS is generally based on the assumption of rational behaviour that users will minimise travel distances to access services and that people will not choose to use overburdened facilities. However, depending on the type of service analysed, people's choice of facility may not be guided by proximity alone. It can, for example, be guided by the capacity available at the facility and / or their perception regarding the quality of service they will receive.

Talen (2003, in Higgs, 2004: 123) has described a number of measures applied when measuring accessibility such as container, coverage, gravity, travel time and distance. The most basic container measures compare the supply of services with the potential demand for services in a defined area (Higgs, 2004: 122-3). Such measures look at, for example, the number of hospitals per hundred thousand people in an area while assuming that there is no cross boundary flow of people from adjoining areas. This may overestimate the actual supply of services to the population, or the other way around. To overcome such shortcomings, GIS and related network analysis tools have been used to allocate the flows from demand origins to one or more supply centres, and use this to demarcate supply centre catchment areas, or estimate the flows attracted by each supply centre (Morojele *et al.*, 2003:6). This type of analysis is not container based, however allocation to a facility (potential accessibility) does not guarantee utilisation (revealed accessibility) of the services available. Intuitively, there could be a significant gap between potential and revealed accessibility (Lin *et al.*, 2005:1882). This is because people may, in some instances, travel outside of their place of residence to seek the desired services elsewhere than from their closest facility. Documented empirical studies that have focused on the actual utilisation or revealed accessibility are usually much more limited (Lin *et al.*, 2005:1881). The actual level of discrepancy has not been studied extensively, therefore it is difficult to accept or discredit a GIS-based approach.

An important facet of this study has to do with revealed access to facilities based on actual usage and origins of users at each facility. This, in a way, responds to the need of measuring access by the level of use and not simply by the presence of a facility. However, this is complex since there is no direct correspondence between need and use. McLafferty (2003:27), for example, has pointed

out that although utilisation may not reflect need, it may reflect contextual and service related factors such as service affordability. It was found in the literature that research on the actual utilisation of the available health care services has not been looked into extensively. The absence of health service utilisation databases such as digital patient registers has been recognised as a gap in existing research while there is ample evidence on the need for this type of analyses that incorporate utilisation rates.

3. OBJECTIVES / RESEARCH QUESTIONS

The overall aim of this research as a whole was to determine, based on the current population, what and where the current demand for public health care is. To achieve the above aim three inter-related objectives are set within the context of GIS-based accessibility analysis:

1. To determine three public primary health care demand scenarios based on a combination on three variables.
2. To model potential catchment areas of the selected facilities using the demand scenarios.
3. To compare utilisation data available (in the form of headcounts) with the current capacity or threshold and also with the demand that has been allocated in terms of the catchment area analysis.

4. APPROACH & METHODOLOGY

4.1 Study area

- 4.1.1 The study area is the City of Johannesburg in the Gauteng province; the largest of the nine South African Metropolitan Municipalities in terms of population and local government budget and revenue. From the north side it stretches from the City of Tshwane to the south side of Emfuleni Local Municipality. Its eastern and western boundaries stretch towards Ekurhuleni Municipality and Mogale City respectively. This highly urbanised City is divided into seven administration or planning regions: A-G. The boundaries of these seven regions are shown in **Error! Reference source not found.** Service delivery direction within the City is set and incorporated within these regions (Richards *et al.*, 2006:17). According to StatsSA 2011 Census, the City of Johannesburg had a total population of 4 434 827 people made up primarily of a young population aged between 30 and 39 years. This total population translates roughly into 1.3 million households (2011 City of Johannesburg Integrated Development Plan). The City of Johannesburg remains one of the quickest growing locations globally (Ahmad *et al.*, 2010:5). According to StatsSA Census, between the years 2001 and 2011 the city's population increased by 27%. Rapid population growth in the City has been attributed to in-migration. With the inner city seen as the core of economic production, areas such as Hillbrow and Yeoville have experienced a great influx of people and rapid occupancy by migrants seeking employment. The visible results of this urban growth magnitude occur in the form of substandard housing and overcrowding. According to the Johannesburg Development Agency (2013) the City of Johannesburg is the leading metropolitan gateway for migrants from other provinces across South Africa as well as international migrant, and as an economic, is the first choice of destination by job seekers. In a context of rapidly shifting settlement dynamics, the City of Johannesburg faces the challenge of providing quality services at affordable rates to all residents (Van Rooyen *et al.*, 2009:65). The high and middle income groups live largely in the suburbs of Randburg, Rosebank, Sandton and Midrand which are located in the centre of the municipality and towards the north. In the high dense areas of the southern suburbs and on the north periphery lives the low income population; these are areas such as Soweto, Ivory Park, Diepsloot and Alexandra. These areas host extremes of poverty, high density informal settlement and informal trade (Ahmad *et al.*, 2010:5). Most of these informal settlements lack proper roads, access to piped water and have poor sanitation.

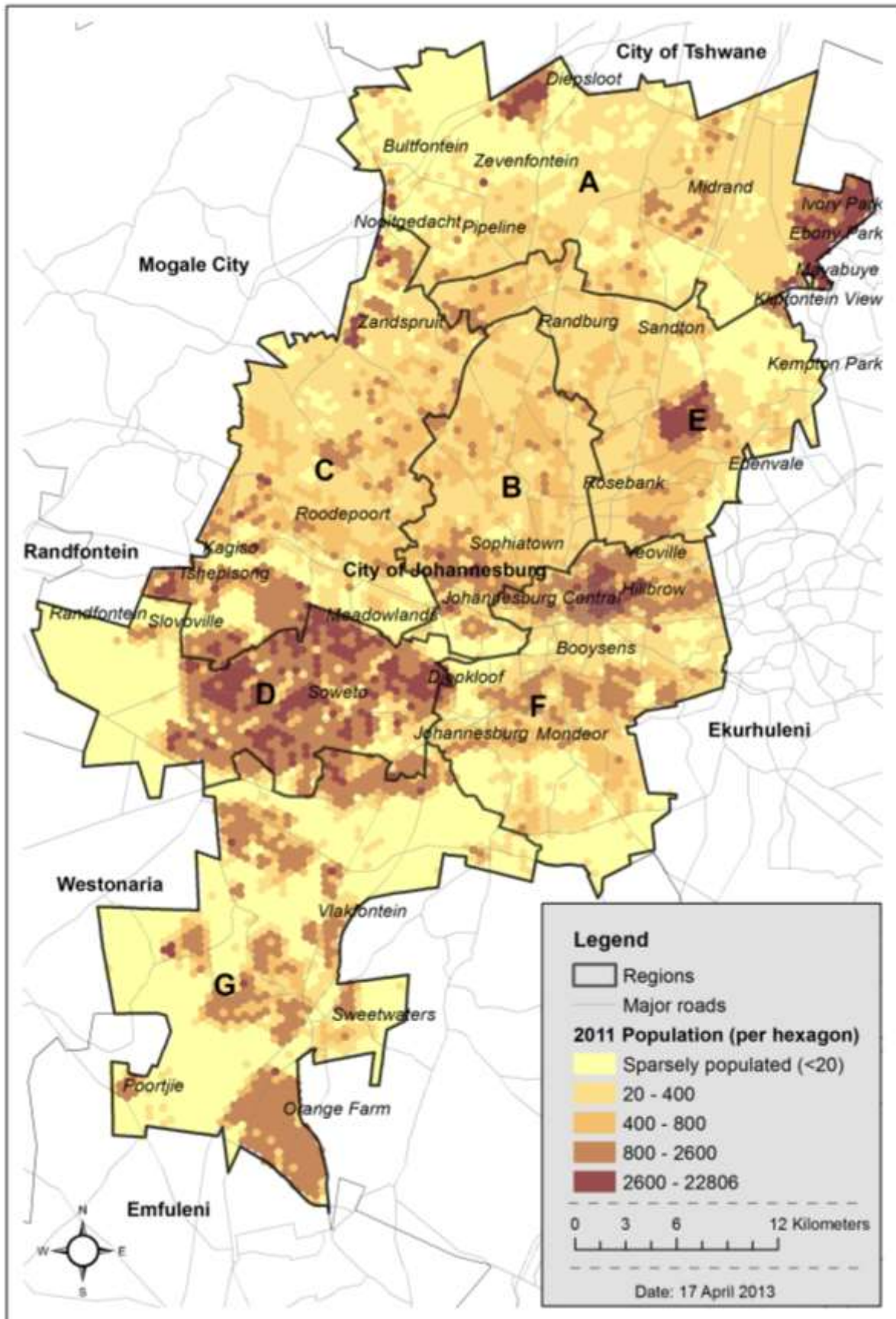


Figure 1: 2011 Population Distribution in the City of Johannesburg

4.2 Generic Data Collection and Preparation

4.2.1 City of Johannesburg:

A spatial layer of the City of Johannesburg was obtained from the Council for Scientific and Industrial Research (CSIR). This layer was used to produce spatially smaller analysis units of hexagons of 20 hectares each. In dividing the spatial layer into hexagons, the total area taken into account coincides with the city borders or boundaries. The reason for using the hexagons as analysis units is that it allows the analysis output to be produced on a more detailed level than working with, for instance sub-places, which allows the identification of problem areas more accurately (Green *et al.*, 2012:6). Secondly, the hexagons give a better distance estimate as the radius is the same for all points on the perimeter. A set of the 2008 Eskom's Spot Building Count (SBC) for the City of Johannesburg was also obtained from CSIR to be used as a proxy layer for the population distribution within the City.

4.2.2 Population data:

The population data was acquired from StatsSA and based on the Census 2011. The City's total population served as the basis for determining the demand for health care services. When working with health care services, the data requires specific age (based on two age groupings of >5 and <5 years) and income breakdown. Following income group studies by Van Wyk and Van Aardt (2008:5), the StatsSA 2001 census income groups (R0-R9 600, R9 601-R38 400, R38 401-R153 600, R153 601-R614 400, R614 400+) were adjusted with the change in consumer price index (CPI) between 2001 and 2011. The groups therefore changed to R0-R17 200, R17 201-R68 500, R68 501-R273 800, R273 801-R1 095 200 and R1 095 200+. The adjusted income groups were then amended to coincide with the 2011 Census income groupings of R0-R19 200, R19 201-R76 800, R76 801-R307 200, R307 201-R1 228 800 and R1 229 801+. The first two groups were consolidated into the low income, the second group became middle income and the last two groups became high income.

4.2.3 Transport network:

A 2010 AfriGIS (Pty) Ltd version routable vector layer of the provincial and major roads, including the in-depth street centre lines of the study area was obtained from the CSIR. The road network was based on a subset of the transport network data used in an earlier accessibility study of the City of Johannesburg by the CSIR. This subset could be readily used since the attribute data was thus already cleaned and prepared when obtained. The road network was sufficiently complete and highly accurate as it covered the complete road and street network of the study area. A road network was used for the reason that it takes into consideration the natural and the built environment of the study area and can therefore accurately simulate the way in which people would travel to facilities contradictory to using straight-line distance.

4.2.4 Facility data:

The 2011 facility dataset was obtained from the Gauteng Provincial Health Department (GPDH). The facilities selected for the analysis were mainly those that offered primary health care services. This simply means those facilities that would act as a first point with the health care delivery system. These were facilities offering level one services of the primary health care package and thus excluded those facilities offering trauma and casualty services. The facilities were further selected on the basis of the following criteria:

- i. Administered by the public sector,
- ii. Had a fixed geographical location,
- iii. Had accessible attribute data about professional nurse clinical work days, facility operating days and hours.

- iv. Had the total headcounts for year 2011. A database of the headcounts (actual usage rates) of the actual visits to the facilities of the study area, recorded per facility, was obtained.

All facilities that met the above selection criteria were analysed. In total they were 10 Community Health Centres (CHCs) and 106 Clinics, thus 116 in total. Using the capacity calculation equation (see Mokgalaka *et al.*, 2014), as developed by the CSIR, each facility was separately specified a capacity, i.e. translated into the potential to accommodate visits (visits to a professional nurse in a facility).

4.2.5 ETR.Net data:

Since there was no residential address database of all the patients who visit the City's primary health care facilities, a 2011 Electronic Tuberculosis Register (ETR.Net data) was considered as a good proxy or representation to serve as revealed demand data in this study. This was considered a good representative sample of actual visits because the patient register stores data from the initial visit (first contact visit before knowing health status) that people made before the TB diagnosis. Literature (Al-Taiar *et al.*, 2010 and Scott *et al.*, 2002) has also highlighted the practicality of using population based cancer and TB registers as good potential patient register proxy datasets as they comprise the patient's residential addresses. A soft-copy database of TB patient records was obtained from GPDH.

4.2.6 Access standard:

Access standards are of cardinal importance in an accessibility analysis as they can either determine or indicate, spatially, the level of access of a facility. In addition, if no distance is set or set too high then all demand will be counted for at all facilities. The 5km National Department of Health Standard for primary health care was applied in this study (see National Department of Health, 2011 & 2000). The 5km travel distance standard was positively applied in this study because it was also specifically tailored based of the socio-economic context of the study area in question by the CSIR together with the GPDH for an accessibility study in 2012 (see Green *et al.*, 2012). The socio-economic aspect was taken into consideration as this has an influence on the kind of transport mode mostly likely to be available and used, which in turn influences the ease with which people can access a given facility within a given distance (Mokgalaka *et al.*, 2011:4). This 5km travel distance standard equates to a normal walking time of a maximum of one hour.

4.3 Population Data Manipulation

The population demand for public primary health care was considered to be all the people who do not have medical aid insurance, i.e. the uninsured population. Three methods to calculate the uninsured population were derived based on a combination of three variables from the population data: (a) household income category, (b) age, and (c) average facility visits. The three methods are labelled scenarios for (ease of) reference in this paper and the following discussions specifies how they were determined.

4.3.1 Calculating uninsured population

In order to determine public primary health care demand in the City of Johannesburg, the target population was considered to be the uninsured population, i.e. those people without medical aid coverage. In this study it was assumed that people without medical aid coverage were most likely to use primary health care facilities provided by government as a first point of contact with the health care delivery system. Three scenario types of uninsured population were determined. These scenarios were derived using the 2011 General Household Survey (GHS) data on medical aid coverage by total annual household income and the 2011 Census population data. For the reason that the GHS data was only available on the lowest spatial level of metropolitan area and non-metropolitan area distinction, data was then acquired on a provincial level. This is because it was going to be difficult to extract only the City of

Johannesburg data from the Gauteng Provincial level data since this province has three metropolitan areas, namely City of Johannesburg, City of Tshwane and Ekurhuleni Metropolitan Area. Based on the GHS data it was then determined that in 2011 75% of population in the Gauteng Province were medically uninsured and 25% medically insured. This ratios were then applied to the total population of City of Johannesburg for the 2011 Census population data 2011: $4\,434\,828 * 0.25 = 1\,105\,841$ insured population and $4\,434\,828 * 0.75 = 3\,328\,987$ uninsured population. The resultant data was then manipulated accordingly for the three scenario types:

- i. **Scenario 1:** the status of uninsured was proportionally allocated to the population in each income category using the uninsured population global total for the study area as the control variable. The ratios as provided by StatsSA were as follows:
 $R0 - R19\,600 = 84\%$
 $R19\,600 - R76\,400 = 92\%$
 $>R76\,400 = 47\%$
- ii. **Scenario 2:** all persons in the low income group and 50% of persons in the middle income group were assigned the status of uninsured.
- iii. **Scenario 3:** persons from the highest income category were first assigned the status of “insured” (insured population estimate as determined above to be 1 105 841 people or 25% of the total population), and then people from the next highest income category and so on until the total insured population number has been assigned. Once the total number of insured population was reached, the remainder of the population was then considered to be uninsured.

The uninsured population for each scenario were then translated into potential visits likely to be generated by the population. In accordance to the information supplied by the GPDH and the eThekweni Department of Health for the Geographic Accessibility Study of Social Facility and Government Service Points for the Metropolitan Cities of Johannesburg and eThekweni by the CSIR in 2012, demand (total number of health visits) was calculated on the agreed assumption that for every child (5 years and younger): 5 visits would be generated in eThekweni and 4 visits in Gauteng per year; and for all persons older than 5 years: 3.5 visits in eThekweni and 3 in Gauteng per year were considered adequate (Green *et al.*, 2012:9). The visits assumption for eThekweni was also applied in the 2008 study by the CSIR on Accessibility Mapping and Optimisation of Community Social Services in the eThekweni Metropolitan Area (Green *et al.*, 2008:4-1). In this study the count of 4 annual visits for >5 years and 2 annual visits for <5years for City of Johannesburg which emanated from the countrywide 2011 PHC Utilisation study conducted by the Health Systems Trust (2011, HST) was applied. Meaning that the >5 years uninsured population were multiplied by 4 and <5 by 2. This resulted in the following total visits for each scenario:

- i. Scenario 1 = 7 124 518 visits per annum
- ii. Scenario 2 = 7 149 055 visits per annum
- iii. Scenario 3 = 7 416 886 visits per annum

The visits per scenario were then accurately distributed on to the analysis units using the principles of dysametric mapping (see Mans, 2012). It is after this data manipulation process that the analysis was undertaken. The data was set up in such a way that the analysis procedures were rerun for each scenario.

4.4 Data Analysis

The steps taken to achieve the objectives mentioned above in Section 3 are briefly outlined. The analysis was essentially based on the iterative use of two GIS softwares; a customised

GIS software known as Flowmap and ESRI's ARCGIS. Flowmap was developed by the University of Utrecht's Department of Geographical Sciences specifically for undertaking accessibility analysis for the strategic evaluation of sets of facilities based on both distance and capacity.

The first step in the analysis was to determine the travel distance from all the areas in the City of Johannesburg to the closest primary health care facility. This step was solely based on travel distance to each facility and thus excluded the capacity parameter. This means that the capacity of the facility to accommodate the visits was not taken into consideration. Apart from placing the study area in an accessibility spatial context, this step was done to essentially indicate (1) the distribution of the facilities within the study area, (2) the relative locations of the areas with regards to the facilities and also (3) to show the catchments areas of these facilities irrespective of distance.

GIS tools were applied to model the current situation of potential accessibility with regards to capacity and location of facilities. Using the Flowmap GIS tool, a GIS-based form of catchment allocation modelling was applied to allocate the demand from each origin area (residence) to the closest facility (destination) using a road network. Each origin location represented a value which indicates the demand (scenarios as determined in sub-section 4.3.1), and each destination location has a value which indicates its facility's maximum capacity, or maximum amount of demand it can serve. The assignment allocates origins within a specified access range to the nearest facility with capacity, and stopping the assignment either when capacity has been reached, or when the access range (distance standard) is exceeded. Access routes to facilities are limited to access via a road network where a five km travel distance standard is set. The analysis subsequently demarcates catchment areas around each facility.

The modelled demand from the catchment area analysis results (allocated demand) from each of the three scenarios were compared with actual usage rates in the form of headcounts per facility. The headcounts or visits were recorded by the City for the 2011 calendar year. The comparison was done by using the Pearson's correlation coefficient in Microsoft Office Excel 2010 package to determine the relationship between the two variables. That is the relationship between the modelled demand allocated to each facility and headcounts (visits) per facility. This was done fundamentally to examine whether the total demand modelled or allocated per facility correlate with the number of visits actually generated by the city population in the study year. The last task is to use the geocoded addresses from patient register and examine whether the patients used their closest the facility and also to give insight as to how far people actually travelled to seek the health services they needed.

5. RESEARCH ANALYSIS & FINDINGS / RESULTS

As set out in Section 4 above, three sets of demand scenarios were analysed. The three scenarios were analysed to assess the spatial distribution of the population demand relative to the distributions of facilities in general. Although the data and process undertook were discussed in more detail in Section 4, Table 1: Criteria and processes for primary health care analyses below summarises the criteria and processes undertaken in terms of analysing the scenarios in relation to the facilities within the study area.

Table 1: Criteria and processes for primary health care analyses

Description	The facilities selected for the analysis are mainly those that offered public primary health care services and acted as first point of contact with the health service delivery system. Attached to the facility data are attribute data indicating the capacity of the facility.
Facilities analysed	116 primary health care facilities with fixed locations (Clinics and Community Health Centres)
Demand	A. Scenario 1 = 7 124 518 visits per annum B. Scenario 2 = 7 149 055 visits per annum C. Scenario 3 = 7 416 886 visits per annum
Supply	Each facility was separately specified a capacity, i.e. translated into the potential to accommodate visits (visits to a professional nurse in a facility).
Travel mode and access distance	Transport via existing road network, with a distance travel standard: Facilities must be accessed within 5km (National Health Standard)
Analyses undertaken	<ul style="list-style-type: none"> i. Model catchment areas of facilities for each scenario based on capacity and maximum travel distance standard ii. Compare utilisation data (in the form of headcounts) with the current capacity or threshold and also with the demand that has been allocated in terms of the catchment area analysis iii. Using the patient register, examine whether the patients used their closest facility

5.1 Results and findings

Figure 2: Travel distance to closest primary health care facility is a travel distance map for all the population to their closest primary health care facility. Simply put, this means how far people must travel to reach their closest facility if the capacities of the facilities are not taken into consideration. This map then just indicates travel distance to the closest facility. The dark green colours in the first lowest distance bands represent locations that are closest to a facility, while the shades of lime green, yellow to red represents locations that are the furthest from facilities. The areas shaded with a white colour are in most cases areas with no population.

This map only depicts an evaluation of the distance to travel to the closest facility but does not reflect any measure of the facility size or service capacity versus demand. Since the capacity of the facilities was not considered, the travel distance map indicates that the majority of the City's population can reach a facility within a travel distance of 5 km. 53% of the City's population is within 2km and 93% within 5km of a facility. This is particularly good given that the national travel distance standard for primary health care is 5km.

Looking at the travel distance map it can also be deduced that locations of primary health care facilities in the study area are in general well located. The study area has more facilities located in the high population density areas of Region G while low population density and / or sparsely areas of Region A and B have fewer facilities. This shows that the facilities are adequately distributed as they are more in line with the population growth patterns of the study area as a whole.

Figure 3: Facility catchments areas irrespective of distance is a map of the catchment areas of the facilities irrespective of distance and capacity while Figure 4: Allocated demand in distance band (capacity & access distance constrained) is the inverse. Figure 3: Facility catchments areas irrespective of distance is just a simple indication that when capacity and distance parameters are not set, all the demand in the City will be counted for at all facilities. On the other hand, Figure 4: Allocated demand in distance band (capacity & access distance

constrained) indicates the catchment areas in distance bands of the facilities taking into account distance and capacity. It can be noticed that most of the facilities in Region D appear to have catchment areas up to 2km travel distance. This could be due to one of the following reasons; (1) mainly as a result of the closest facilities being technically fully allocated to people living closer to the facility and thus being in reality overburdened or (2) in high density areas, the facility being too small to cope with the local demand or there are few facilities for the total demand in the area.

Figure 5: Scenario 1 total allocated demand and catchment areas (capacity & access distance constrained), Figure 6: Scenario 2 total allocated demand and catchment areas (capacity & access distance constrained) and Figure 7: Scenario 3 total allocated demand and catchment areas (capacity & access distance constrained) indicate the catchment areas of each of the facilities for Scenario 1, 2 and 3 respectively. The catchment area analysis is the same for all the three scenarios; constrained analysis limited by facility capacity and a 5 km travel distance. There is no significant difference in the spatial extent of the catchment areas of the facilities across the three scenarios but that there is a significant demand increase in the number of allocated demand per scenario: scenario 1 (6 711 292) < scenario 2 (6 828 738) < scenario 3 (7 120 648).

The only noticeable difference between the three figures is the catchment area of Rosebank Clinic facility as indicated by the circles in Figure 5: Scenario 1 total allocated demand and catchment areas (capacity & access distance constrained), Figure 6: Scenario 2 total allocated demand and catchment areas (capacity & access distance constrained) and Figure 7: Scenario 3 total allocated demand and catchment areas (capacity & access distance constrained). The facility appears to be spatially accommodating fewer demand areas in Scenario 1 compared to Scenario 2 and 3 where it appears to be accommodating a considerable amount of demand areas for both scenarios. This is because Rosebank Clinic is located in a high income area. Therefore, because in Scenario 2 and 3 a large number of the high income population were assigned the status on medically insured and thus eliminated from the analysis, the facility then accommodates more visits from the surrounding areas. Therefore appear spatially wider in scenario 2 and 3 than in Scenario 1. The demand in Scenario 1, which has more high income population as proportionally allocated, quickly fills up the Rosebank Clinic to its maximum capacity before it could even accommodate visits from other surrounding areas hence it appears to be covering a spatially small area in this scenario.

Overall, the catchment areas of the facilities for the three scenarios appear to follow the same pattern when spatially represented. Facilities that are in close proximity to one another have smaller catchments and therefore geographically appear to be accommodating few demand areas. On the other hand, facilities located further apart have larger catchments and geographically appear to be accommodating a large number of demand areas. The point here is that the size or extent of the catchment is spatial and thus does not equate to demand. In low income areas (Region D for example), where facilities are in close proximity to one another, catchment areas appear spatially smaller as compared to the wider catchment areas in Region B and E for example. But the facilities in these low income areas accommodate 70% of the entire city's health care demand due to the density of the population. This explains why facilities in low dense areas only accommodate or serve 10% of the demand. The remaining 20% is allocated to facilities in the intermediate and sparsely dense areas of Region C and A.

Some facilities located in Region C for example may appear on Figure 5: Scenario 1 total allocated demand and catchment areas (capacity & access distance constrained), Figure 6: Scenario 2 total allocated demand and catchment areas (capacity & access distance constrained) and Figure 7: Scenario 3 total allocated demand and catchment areas (capacity & access distance constrained) as though no demand or visits were allocated to them as the immediate surrounding areas are shaded with white. This is however not the case as the areas allocated to them might not be within the immediate surroundings of the facilities as a result

of dasymetric mapping applied to selecting analysis units with population and thus excluding non-residential area or no population.

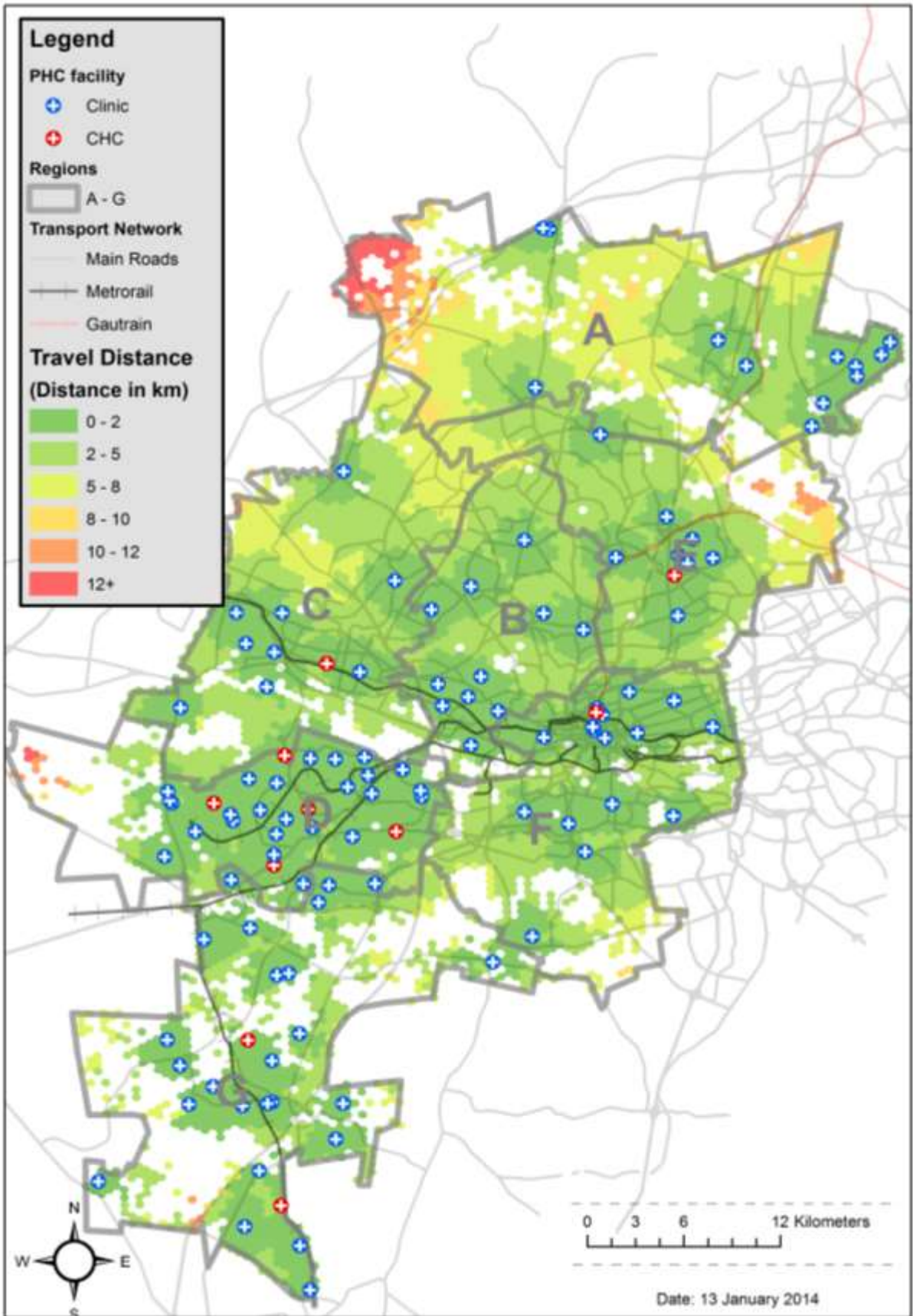


Figure 2: Travel distance to closest primary health care facility

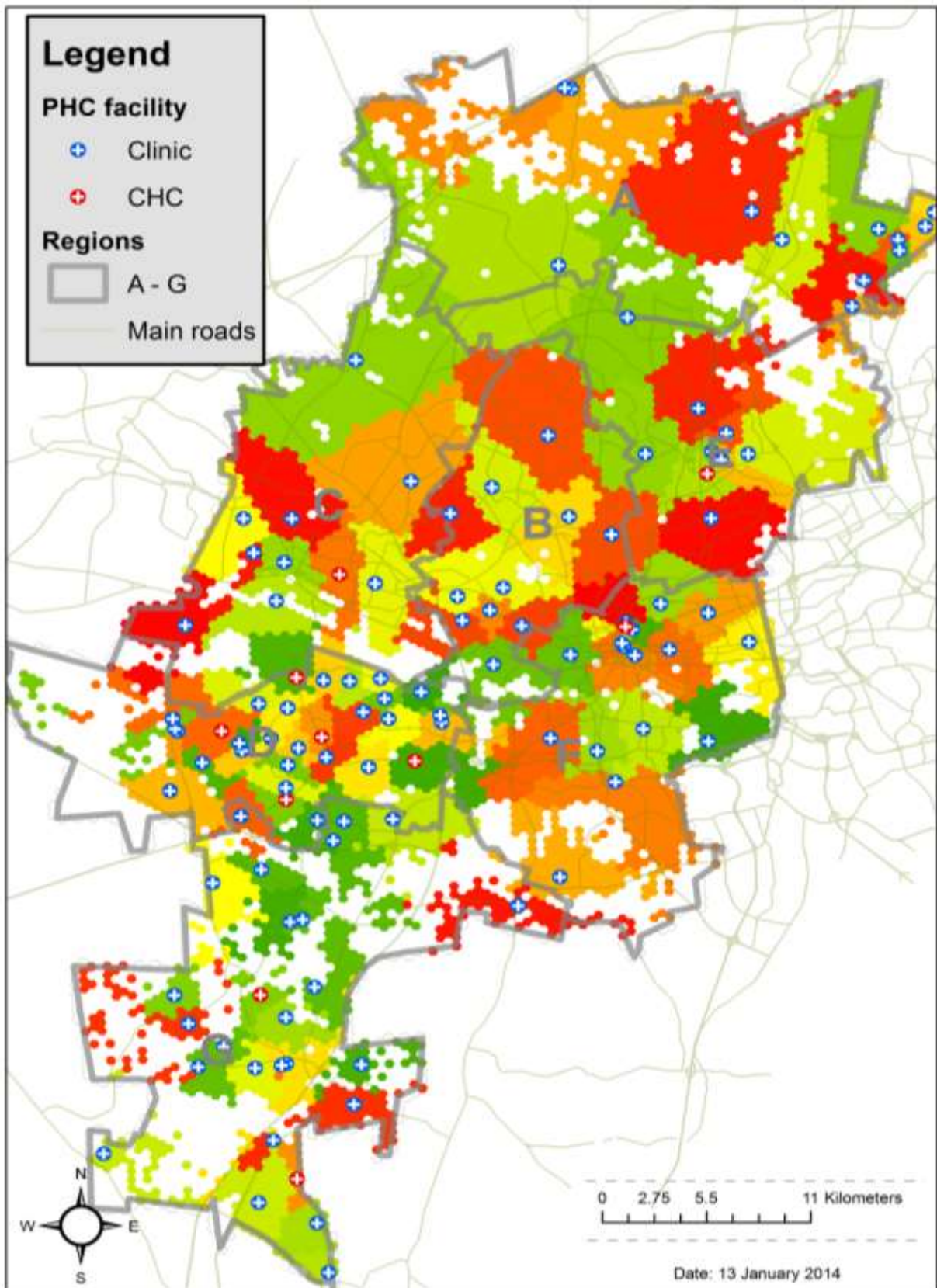


Figure 3: Facility catchments areas irrespective of distance

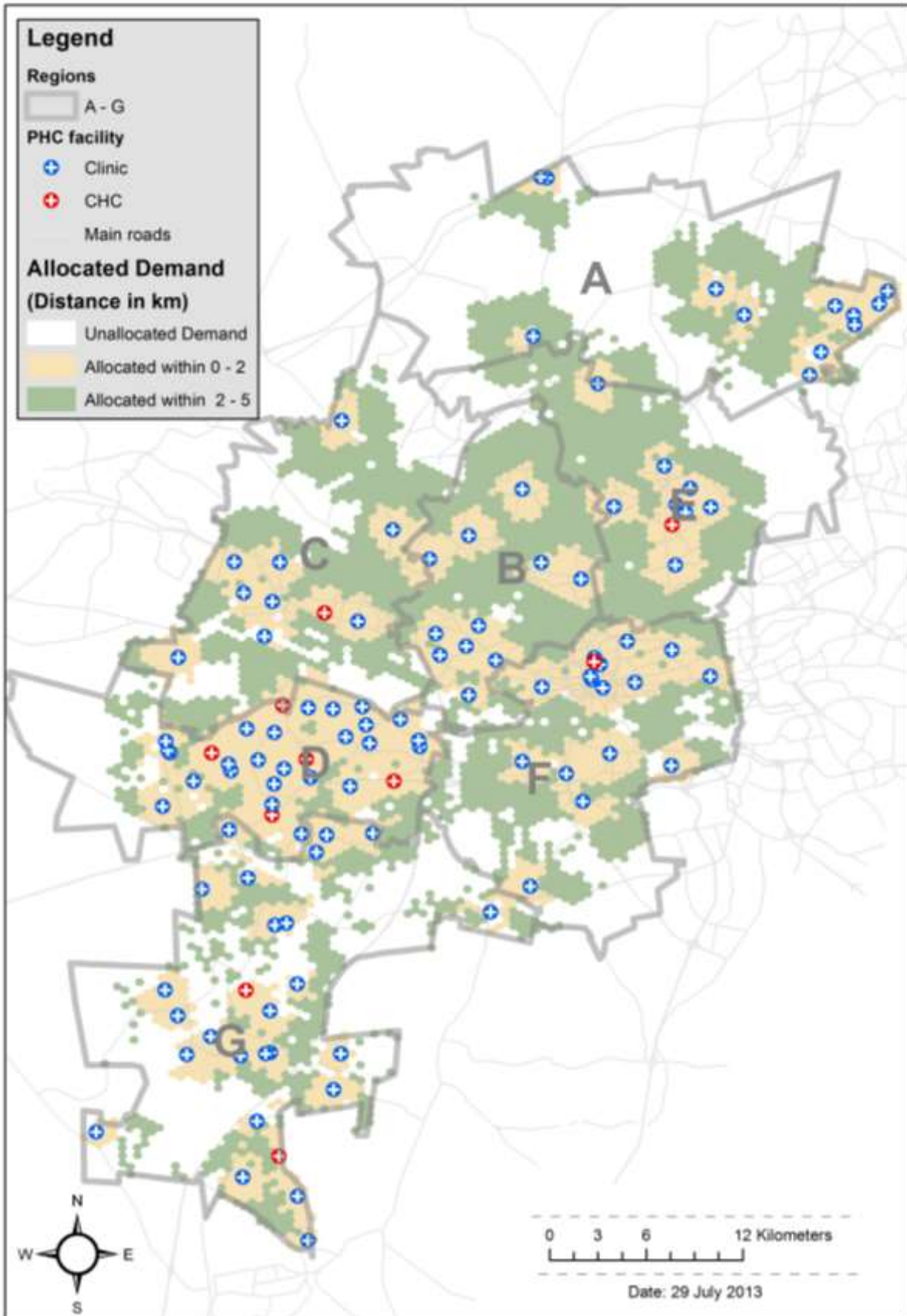


Figure 4: Allocated demand in distance band (capacity & access distance constrained)

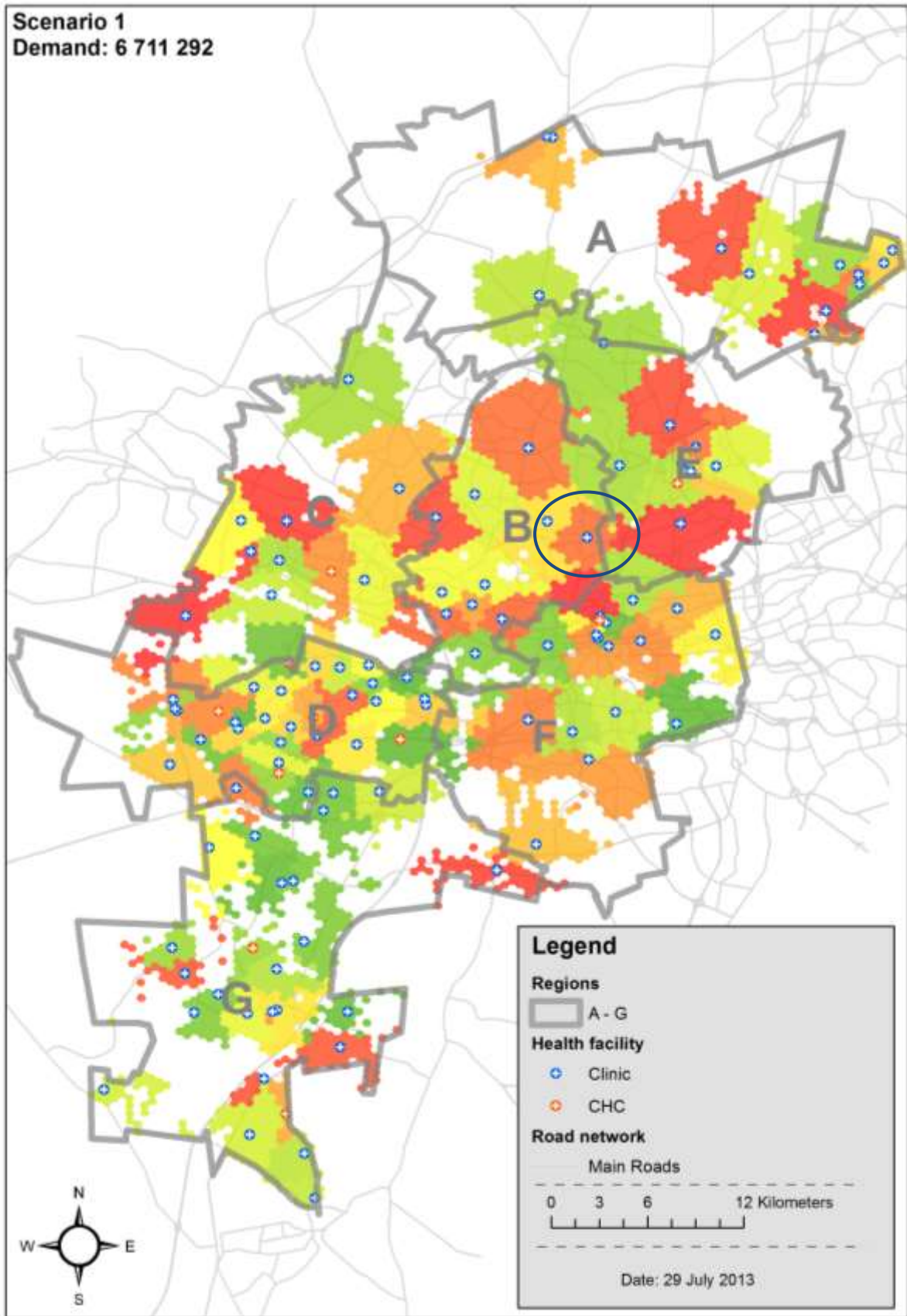


Figure 5: Scenario 1 total allocated demand and catchment areas (capacity & access distance constrained)

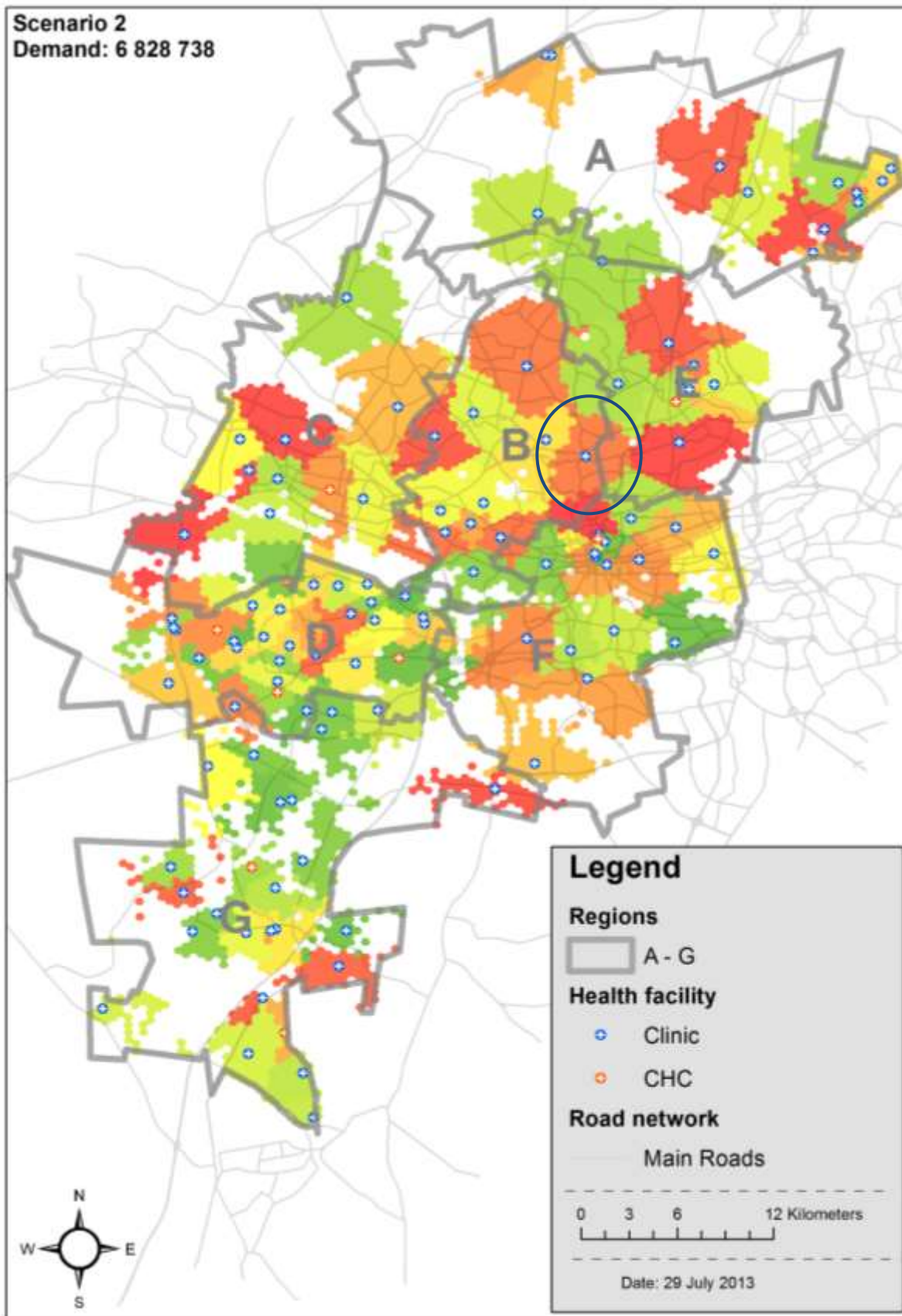


Figure 6: Scenario 2 total allocated demand and catchment areas (capacity & access distance constrained)

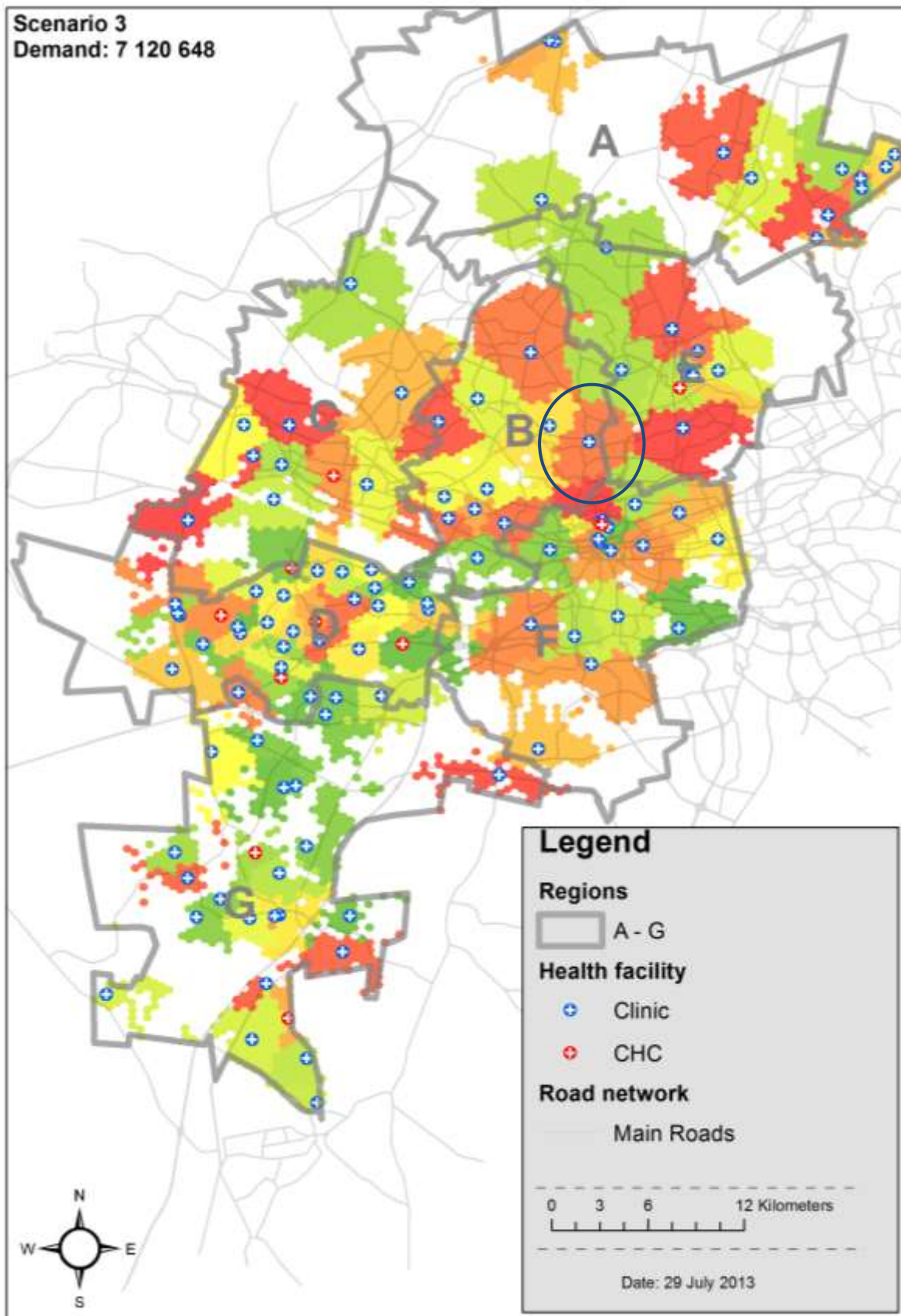


Figure 7: Scenario 3 total allocated demand and catchment areas (capacity & access distance constrained)

The allocated demand from the catchment area analysis results from each of the three demand scenarios are compared with actual usage rates in the form of headcounts per facility recorded by the city. This was done using Pearson Correlation Coefficient in order to reflect the extent of a linear relationship between two data sets; allocated demand for each facility per scenario and actual facility headcounts. The output results indicate that the allocated demand per facility for all three scenarios have a moderate positive correlation with the facility headcounts. When compared to one another, Scenarios 2 and 3 have a slightly higher moderate positive correlation of 0.35 while Scenario 1 has moderate positive correlation of 0.34. The proportion of facilities which have a modelled demand equal to or greater than the headcounts are 53%, 54% and 55% for Scenarios 1, 2 and 3 respectively. This indicates that the approach used to determine the demand for Scenario 3 is a good approach to defining public primary health care demand.

Results from the patient register show that almost 45.26% of the patients from the register did not use their nearest facility as a first point of contact. This means that 44.26% of the patients did not reside in the catchment areas of the facilities they visited. This indicates that many facility users are able and willing to travel further than 5 km to acquire health care services. Findings show that only 1% of the patients reside outside the City's boundary. There is noticeable trend of a considerable number of patients, from the southern suburbs, using facilities in the Central Business District (CBD) of the City of Johannesburg. Various reasons can be attached to these results but it is not possible to identify such reasoning from the data set used in this study. This may include perception of better services, availability of treatment, knowledge of capacity due to long queues at closer facilities, need for specialised procedures, mobility and transport network and workplace located next to a facility. However, it is not within the scope of this study to confirm these reasoning. From a modelling perspective, another related explanation is that the model under-predicts the use of facilities that are further away. A probability variance should be built into the model to avoid generalising rational choice or behaviour.

6. RESEARCH CONTRIBUTION

Research in South Africa over the last twenty to thirty years has added knowledge to the subject of spatial planning of health care services. However, very little seems to have been done about improved methods of determining demand for health care services. Health care planning is a demand-driven process. Therefore service provision in this sector should respond to existing or potential demand. The planning process needs to be largely seen from the perspective of the client where use becomes the most important consideration. Undertaking accessibility analysis for the strategic evaluation of primary health care services using GIS which incorporates utilisation rates has only been used to a very limited extent in South Africa. So this approach can be used to greatly assist in the formulation of district plans and in ensuring that sector facility plans are put in place based on actual demand and usage when it comes to the provision of a range of services. Another key advantage of using accessibility analysis is that it transcends the measurement of facility sufficiency or quantity with respect to its location within the administrative unit in which it is located. This makes it possible to identify spatial service backlogs with respect to residential patterns so as to improve current service access at overburdened focal points where previously not realised. In addition, the actual distance travelled by the patients are analysed to serve as input and give support to the attainment of more equitable access standards to a range of services in a metropolitan context and to test and evaluate optimal facility location, in conjunction with movement patterns.

7. CONCLUDING REMARKS

There will still be a continued need for more robust planning to achieve a more equitable distribution of services in response to the growing need for healthcare. Much work is being done from a selection of accessibility planning approaches that are continuously developed and incorporated in the GIS suite of decision support tools. The focus is on the need for improved

measures of access to local (public) facilities, and the need to find practical tools to support and improve current facility planning practice based on more realistic assumptions (Green et al., 1997:4). This paper has shown that establishing the demand profile for public services is a very important aspect in the planning process. Three different approaches to determining public primary health care demand were created and tested in the study in the absence of accurate patient databases and / or registers. The 3 demand scenarios used in this study tested did not show any significant difference in the spatial extent of each of the catchment areas of facilities but a significant increase in the allocated demand from Scenario 1 through to Scenario 3. The total allocated demand in scenario three was strongly in line with the total number of facility visits (usage rates) recorded in the city and thus had a moderate positive correlation. This indicates that the approach used to determine the demand for Scenario 3 is a good approach to defining public primary health care demand. It is important to regularly test the result outputs from the GIS-based analysis against usage rates or actual data. On an international scale, many studies have used patient registers as demand input when measuring potential accessibility. However, in South Africa, owing to the absence of accurate databases, such capabilities remain untapped.

8. RESEARCH LIMITATIONS

- 8.1 Only facilities with capacity variables were used in the analysis. The variables included geographical locations of all facilities, facility type, population threshold / capacity / number of staff and operation per annum (days / hours). Facilities that didn't have these variables were excluded. The selected facilities are therefore a representative of the supply of public primary health care services in the City. This excludes hospitals that offer primary health care.
- 8.2 A residential address database of all patients did not exist because the majority of patients retain their medical information. The only data available with residential addresses were clinic retained cards for TB chronic patients and the ETR.Net database. The ETR.Net database was used as a proxy of the patient residential address database.
- 8.3 The ETR.Net database had 23 294 TB cases or records which initially reported to primary health care facilities in the City of Johannesburg. A large amount of time was spent on geocoding the records because of issues such as errors and inconsistencies in the residential addresses. Some of the records were not geocode-able as they either did not have residential address or had incomplete addresses, and thus excluded from the analysis.

9. FURTHER RESEARCH

It was found in the literature that data on the actual utilisation of services and / or facilities is not available especially in usable formats. The absence of health service utilisation databases such as digital patient registers has been recognised as a gap in existing research while there is ample evidence on the need for this type of analyses that incorporate utilisation rates. There is also a need for tools to improve demand estimate which do not only use place of residence as the origin but as well as the workplace because increasingly sophisticated measures can be constructed by computing the measure separately for different trip purposes, different travel modes and travel times, different age, sex, and occupational groups.

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